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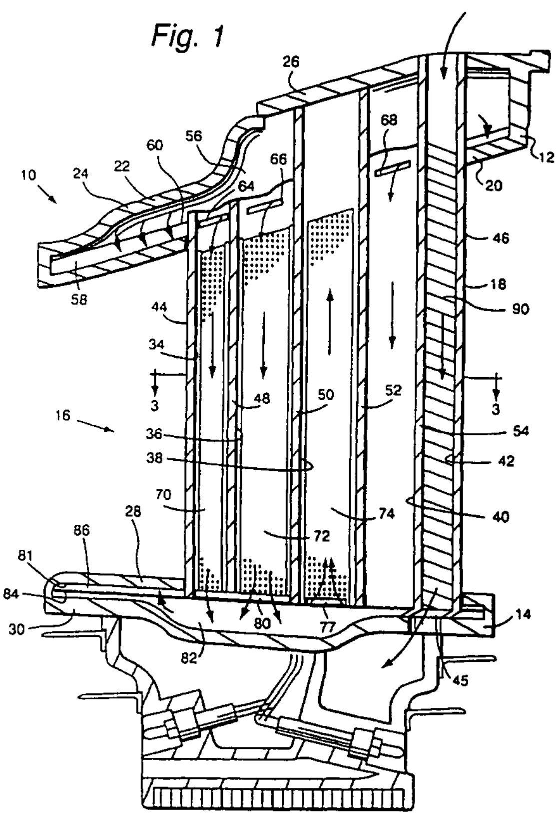
(54) Turbine stator vane segment having internal cooling circuits

(57) A turbine stator vane includes outer and inner walls (20, 28) each having outer and inner chambers and a vane (18) extending between the outer and inner walls. The vane includes first, second, third, fourth and fifth cavities (34, 36, 38, 40, 42) for flowing a cooling medium. The cooling medium enters the outer chamber of the outer wall, flows through an impingement plate (60) for impingement cooling of the outer band wall defining in part the hot gas path and through openings (64, 66, 68) in the first, second and fourth cavities for flow radially inwardly, cooling the vane. The spent cooling medium flows into the inner wall and inner chamber for flow through an impingement plate (84) radially outwardly to cool the inner wall. The spent cooling medium flows through the third cavity (38) for egress from the turbine vane segment from the outer wall. The first, second or third cavities contain inserts (70, 72, 74) having impingement openings for impingement cooling of the vane walls. The fifth cavity (42) provides air cooling for the trailing edge.

Fig. 1



Description

[0001] The present invention relates generally to land-based gas turbines, for example, for electrical power generation, and particularly to internal cooling circuits for the nozzle segments of the gas turbine.

[0002] Traditionally, compressor bleed air is extracted from the turbine's compressor for cooling the turbine blades and nozzles. Diversion of cooling air, however, represents a parasitic loss to turbine efficiency. More recently, advanced gas turbine designs have recognized that the hot gas path flow temperature could exceed the melting temperature of the turbine components, necessitating a different cooling scheme to protect those hot gas path components during operation. Steam as a cooling medium has been recognized as superior to air because steam has a higher heat capacity. A gas turbine employing steam as a cooling medium for the nozzle segments has been proposed, for example, in U.S. Patent No. 5,674,766 of common assignee herewith.

[0003] In the cooling scheme set forth in that patent, the inner and outer walls or bands of the nozzle segments between which the nozzle vanes extend are compartmentalized to provide impingement cooling along the outer and inner walls of the segment. Cooling steam is also provided along the walls of the vanes. To accomplish that, the cooling steam is supplied to a first chamber of the outer wall, where it passes through impingement openings in an impingement plate for impingement cooling the outer wall. The steam is then passed radially inwardly through the first and fifth cavities of each stator vane for flow through inserts in those cavities. The inserts have openings and the steam flows through the openings to impingement cool registering portions of the stator vane walls. The steam then flows into an inner chamber of an inner wall and reverses direction for flow radially outwardly through openings in an impingement plate to impingement cool the inner wall. The spent cooling medium then flows radially outwardly through three intermediate cavities, each having an insert with openings for impingement cooling the adjacent walls of the vane. The spent cooling steam then flows outwardly of the segment.

[0004] Additionally, air is supplied to a cavity extending adjacent the trailing edge of the vane for cooling the trailing edge. The air flows past turbulators and exits into the hot gas stream through openings in the trailing edge. While the foregoing described design has many advantages, it is desirable to have a more robust design with reduced casting costs and complexity, as well as a reduced number of inserts.

[0005] In accordance with a preferred form of the present invention, a nozzle stage is provided having a cooling circuit, e.g., steam and air, of reduced complexity and cost, while meeting cycle requirements. Particularly, the cooling scheme of the present invention for the nozzle stage includes outer and inner bands with vanes extending therebetween. Similarly as in the above-mentioned patent, the inner and outer bands are compartmentalized for impingement cooling of the walls defining the gas path. The present invention, however, provides a cooling circuit within each vane having a flow pattern significantly different from the flow pattern of the prior patent affording the above-mentioned advantages. The present invention provides first, second, third, fourth and fifth cavities between the inner and outer bands of each vane segment. The cavities in each vane are arranged sequentially in that order from the leading edge to the trailing edge. After impingement cooling the gas path wall of the outer band, steam from the outer band flows generally radially inwardly through inserts in the first and second cavities and through openings in the inserts for impingement cooling the registering wall surfaces of the vane. Steam is also supplied to the fourth cavity for flow radially inwardly. However, the fourth cavity does not have an insert and the walls of the vane defining the fourth cavity are not impingement cooled. Rather, they are convectively cooled. Thus, the cooling medium is supplied the first, second and fourth cavities at a relatively low temperature, affording improved cooling adjacent the leading and trailing edges, the hottest portions of the vanes. The steam flowing into the inner band compartment passes through an impingement plate for impingement cooling of the inner band. Spent cooling steam is supplied to the third vane cavity. An insert in the third cavity has openings for impingement cooling of the registering wall surfaces of the vane. The spent cooling steam then flows outwardly of the third cavity for flow generally radially outwardly of the vane segment. The fifth cavity is air-cooled by compressor bleed air. Turbulators are also disposed in the fifth cavity. However, the fifth cavity is closed and does not exhaust air to the hot gas path stream. Rather, the spent cooling air is exhausted into the wheelspace.

[0006] In a preferred embodiment according to the present invention, there is provided a turbine vane segment, comprising inner and outer bands spaced from one another and having inner and outer walls, respectively, in part defining a gas path through the turbine, a vane extending in the gas path between the inner and outer bands and having leading and trailing edges, the vane including a plurality of discrete cavities between the leading and trailing edges and extending lengthwise of the vane for flowing a cooling medium, a cooling medium inlet for the segment for enabling passage of the cooling medium into a compartment of the outer wall, the cavities including first, second, third, fourth and fifth cavities in sequential order from the leading edge toward the trailing edge, the vane having openings in communication with the compartment and the first, second and fourth cavities to enable passage of the cooling medium from the compartment into the first, second and fourth cavities for flow in a generally radially inward direction along the first, second and fourth cavities, the vane having openings in communication between a compartment of the inner wall and the first, second and

fourth cavities for flowing the cooling medium from the first, second and fourth cavities into the compartment of the inner band, the vane having an opening in communication with the compartment of the inner band and the third cavity for flowing the cooling medium generally radially outwardly through the third cavity and outwardly of the vane segment.

[0007] In a further preferred embodiment according to the present invention, there is provided a turbine vane segment, comprising inner and outer bands spaced from one another and having inner and outer walls, respectively, in part defining a gas path through the turbine, a vane extending in the gas path between the inner and outer bands and having leading and trailing edges, the vane including a plurality of discrete cavities between the leading and trailing edges and extending lengthwise of the vane for flowing a cooling medium, a first cover for the outer band spaced outwardly of the outer wall, a first impingement plate between the first cover and the outer wall in part defining outer and inner chambers on opposite sides of the impingement plate, a cooling medium inlet for the segment for enabling passage of the cooling medium into the outer chamber, the impingement plate having openings for flowing the cooling medium from the outer chamber into the inner chamber through the openings for impingement cooling of the outer wall, the cavities including first, second, third, fourth and fifth cavities in sequential order from the leading edge toward the trailing edge, the vane having openings in communication with the inner chamber and the first, second and fourth cavities to enable passage of the cooling medium from the inner chamber into the first, second and fourth cavities for flow in a generally radially inward direction along the first, second and fourth cavities, a second cover for the inner band spaced inwardly from the inner wall, a second impingement plate between the second cover and the inner wall in part defining outer and inner chambers on opposite sides of the second impingement plate, the vane having openings in communication with the inner chamber of the inner wall and the first, second and fourth cavities for flowing the cooling medium from the first, second and fourth cavities into the inner chamber of the inner band, the second impingement plate having openings for flowing the cooling medium from the inner chamber of the inner band through the openings of the second impingement plate into the outer chamber of the inner band for impingement cooling the inner wall, the vane having an opening in communication with the outer chamber of the inner band and the third cavity for flowing the cooling medium generally radially outwardly through the third cavity and outwardly of the vane segment.

[0008] An embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

FIGURE 1 is a schematic side cross-sectional view of a stator vane segment according to the present invention;

FIGURE 2 is a perspective view of inserts for the first, second and third cavities of the vane;

FIGURE 3 is a cross-sectional view taken generally about on line 3-3 in Figure 1;

FIGURE 4 is a cross-sectional view illustrating the vane extension above the outer wall of the outer band and the steam inlet apertures through the vane extension; and

FIGURE 5 is an exploded perspective view illustrating various parts of a stator vane segment in doublet form.

[0009] Referring now to the drawings, particularly to Figure 1, there is illustrated a nozzle vane segment, generally designated 10, comprised of an outer band 12 and an inner band 14 in part defining a hot gas path 16 through the turbine of which the vane segment forms a part. The outer and inner bands 12 and 14 are connected by vanes 18. It will be appreciated that the outer and inner bands and vanes are provided in segments and the segments are disposed in an annular array about the axis of the turbine. The space between the outer and inner bands and containing the vanes defines the gas flow path 16 through the turbine.

[0010] The outer band 12 includes an outer band wall 20 in part defining the hot gas path 16 and a cover 22 formed of forward and aft covers 24 and 26, respectively. The inner band 14 includes an inner wall 28 in part defining the gas path 16 and an inner cover 30.

[0011] The vane 18 extending between the outer and inner bands 12 and 14, respectively, includes, as best illustrated in Figure 5, a vane extension 32 having a forward hook 33 for securing the segment to the fixed casing of the turbine, not shown, and which vane extension facilitates flow of a cooling medium as will become clear from the ensuing description. The vane 18 is divided into cavities, and in a preferred embodiment, the cavities comprise first, second, third, fourth and fifth cavities 34, 36, 38, 40 and 42, respectively. The cavities are arranged in sequence from a leading edge 44 of the vane to the trailing edge 46 by internal ribs 48, 50, 52 and 54. As illustrated in Figure 5, a unitary cover 56 overlies and closes the first and second cavities 34 and 36 and a further vane cover, not shown, overlies cavity 40.

[0012] The outer band 12 includes a compartment 55 (Figure 5) divided into outer and inner chambers 56 and 58, separated from one another by an impingement plate 60. The impingement plate 60 is provided in forward and aft impingement plate sections 61 and 63, respectively, for extending about the vane extension 32. Impingement plate 60 includes a plurality of impingement openings for directing steam from the outer chamber 56 of the outer band to the inner chamber 58 of the

outer band. It will be appreciated that the forward cover 24 includes, as illustrated in Figure 5, a steam inlet 65 for supplying steam to the outer chamber 56. The vane extension 32 includes lateral openings 64, 66 and 68 through the vane extensions into the first, second and fourth cavities 34, 36 and 40, respectively, for delivering spent impingement steam into the cavities.

[0013] Each of the first and second cavities includes an insert open at radially outer ends and closed at radially inner ends. The third cavity has an insert 74 open at the inner end and closed at its outer end. The inserts 70 and 72 in the first and second cavities include a collar adjacent their radial outer ends for directing steam received from the lateral openings 64 and 66 through the open upper ends of the inserts into the interior of the inserts. The inserts 70, 72 and an additional insert 74 in the third cavity 38 include a plurality of impingement cooling openings 75 in the walls thereof for impingement cooling the opposite side walls of the vane.

[0014] The inner band 14 includes a compartment 81 (Figure 1) divided into inner and outer chambers 82 and 86, respectively. The lower ends of the inserts 70 and 72 have cavity guides 79. Guides 79 direct the spent cooling steam into the radially inner chamber 82 radially inwardly of an impingement plate 84 in the inner band 14. Openings 80 in cavity guides 79 meter the spent steam from cavity 36 and provide for instrumentation tubing not shown.

Thus, the cavity guides 79 direct the spent cooling steam into the inner chamber 82 where the steam reverses direction and flows through the impingement cooling openings of the impingement plate 84 for cooling the inner wall 28 of the inner band 14. The insert 74 in the third cavity opens into the outer chamber 86 between the impingement plate 84 and inner wall 28 for returning spent impingement steam through the third cavity and impingement cooling the side walls of the vane adjacent the third cavity. The spent steam then flows through the vane extension to a steam exhaust 87 in the aft cover 26.

[0015] As illustrated in Figure 1, the fourth cavity 40 receives steam through the lateral opening 68 for convective cooling the vane walls, there being no insert in the fourth cavity. The steam passes through the fourth cavity into the inner chamber 82 of the inner band 14 and combines with the spent impingement cooling steam from the first and second cavities for impingement cooling the inner band 28 and return through the third cavity 38.

[0016] The final cavity 42 adjacent the trailing edge lies at its radial outer end in communication with a cooling air inlet port (Figure 5) through the aft cover 26. Cooling air, preferably compressor discharge air, is thus admitted into the fifth cavity 42. A plurality of turbulators 90 are provided along the opposite side walls of the fifth cavity 42 to disrupt the boundary layer of the cooling air and provide efficient cooling of the trailing edge. The spent cooling air exits from the fourth cavity through an opening 45 into the wheelspace of the turbine.

[0017] In use, the steam flows into the outer chamber 56 of the outer band 12 through the steam inlet port 65 in the forward cover 24. The steam necessarily flows through the impingement openings of the impingement plate 60 for impingement cooling the outer wall 20 of the outer band 12. The spent impingement cooling steam flows through the lateral openings 64, 66 and 68 of the first, second and fourth cavities. Because the cavities are closed at their upper ends by cover plates, the steam flows radially inwardly and within the inserts 70 and 72. In the first and second cavities, the steam flows outwardly through the impingement cooling holes in the walls of the inserts for impingement cooling of the registering side walls of the vane. The spent cooling steam from the first and second cavities flows radially to the inner band 14 exiting into the inner chamber 82 through the guides 79. The steam from the lateral opening 68 flows through the fourth cavity 40 in a radial inward direction to convectively cool the vane walls and into the chamber 82. The steam in chamber 82 from cavities 34, 36 and 40 flows through impingement openings in impingement plate 84 into the outer chamber 86 of the inner band 14. This spent cooling steam lies in communication with the radial inner end of the third cavity insert 74 for flow radially outwardly along the insert 74. The returning steam flow also flows through impingement openings in the insert 74 for impingement cooling of the opposite side walls of the vane adjacent the third cavity. The spent steam then flows out of the segment through the steam exit port 87 in the aft cover 26. Simultaneously, compressor discharge air flows into the fifth cavity 42 and radially inwardly therealong for cooling the trailing edge 46. The spent cooling air discharges through the inner band into the wheelspace of the rotor.

Claims

1. A turbine vane segment, comprising:

   inner and outer bands (14, 12) spaced from one another and having inner and outer walls (28, 20), respectively, in part defining a gas path (16) through the turbine;

   a vane (18) extending in the gas path between said inner and outer bands and having leading and trailing edges (44, 46), said vane including a plurality of discrete cavities (34, 36, 38, 40, 42) between the leading and trailing edges and extending lengthwise of said vane for flowing a cooling medium;

   a cooling medium inlet (65) for said segment for enabling passage of the cooling medium into a compartment of said outer wall;

   said cavities including first, second, third, fourth and fifth cavities (34, 36, 38, 40, 42) in sequential order from said leading edge toward said

trailing edge, said vane having openings (64, 66, 68) in communication with said compartment and said first, second and fourth cavities to enable passage of the cooling medium from said compartment into said first, second and fourth cavities for flow in a generally radially inward direction along said first, second and fourth cavities;

said vane having openings (80) in communication between a compartment of said inner wall and said first, second and fourth cavities for flowing the cooling medium from said first, second and fourth cavities into the compartment of said inner band;

said vane having an opening (77) in communication with said compartment of said inner band and said third cavity for flowing the cooling medium generally radially outwardly through said third cavity and outwardly of the vane segment.

2. A turbine vane segment, comprising:

inner and outer bands spaced from one another and having inner and outer walls, respectively, in part defining a gas path through the turbine;

a vane extending in the gas path between said inner and outer bands and having leading and trailing edges, said vane including a plurality of discrete cavities between the leading and trailing edges and extending lengthwise of said vane for flowing a cooling medium;

a first cover for said outer band spaced outwardly of said outer wall, a first impingement plate between said first cover and said outer wall in part defining outer and inner chambers on opposite sides of said impingement plate, a cooling medium inlet for said segment for enabling passage of the cooling medium into said outer chamber, said impingement plate having openings for flowing the cooling medium from said outer chamber into said inner chamber through said openings for impingement cooling of said outer wall;

said cavities including first, second, third, fourth and fifth cavities in sequential order from said leading edge toward said trailing edge, said vane having openings in communication with said inner chamber and said first, second and fourth cavities to enable passage of the cooling medium from said inner chamber into said first, second and fourth cavities for flow in a generally radially inward direction along said first, second and fourth cavities;

a second cover for said inner band spaced inwardly from said inner wall, a second impingement plate between said second cover and said inner wall in part defining outer and inner chambers on opposite sides of said second impingement plate, said vane having openings in communication with said inner chamber of said inner wall and said first, second and fourth cavities for flowing the cooling medium from said first, second and fourth cavities into said inner chamber of said inner band, said second impingement plate having openings for flowing the cooling medium from said inner chamber of said inner band through said openings of said second impingement plate into said outer chamber of said inner band for impingement cooling said inner wall;

said vane having an opening in communication with said outer chamber of said inner band and said third cavity for flowing the cooling medium generally radially outwardly through said third cavity and outwardly of the vane segment.

3. A turbine vane segment according to Claim 1 or Claim 2 including openings (43, 45) through said inner and outer walls for flowing a second cooling medium generally radially inwardly along said fifth cavity.

4. A turbine vane segment according to Claim 3 wherein said fifth cavity lies along the trailing edge of said vane and comprises the last of said cavities in sequential order from the leading edge to the trailing edge.

5. A turbine vane segment according to Claim 1 or Claim 2 wherein said vane has solely five cavities.

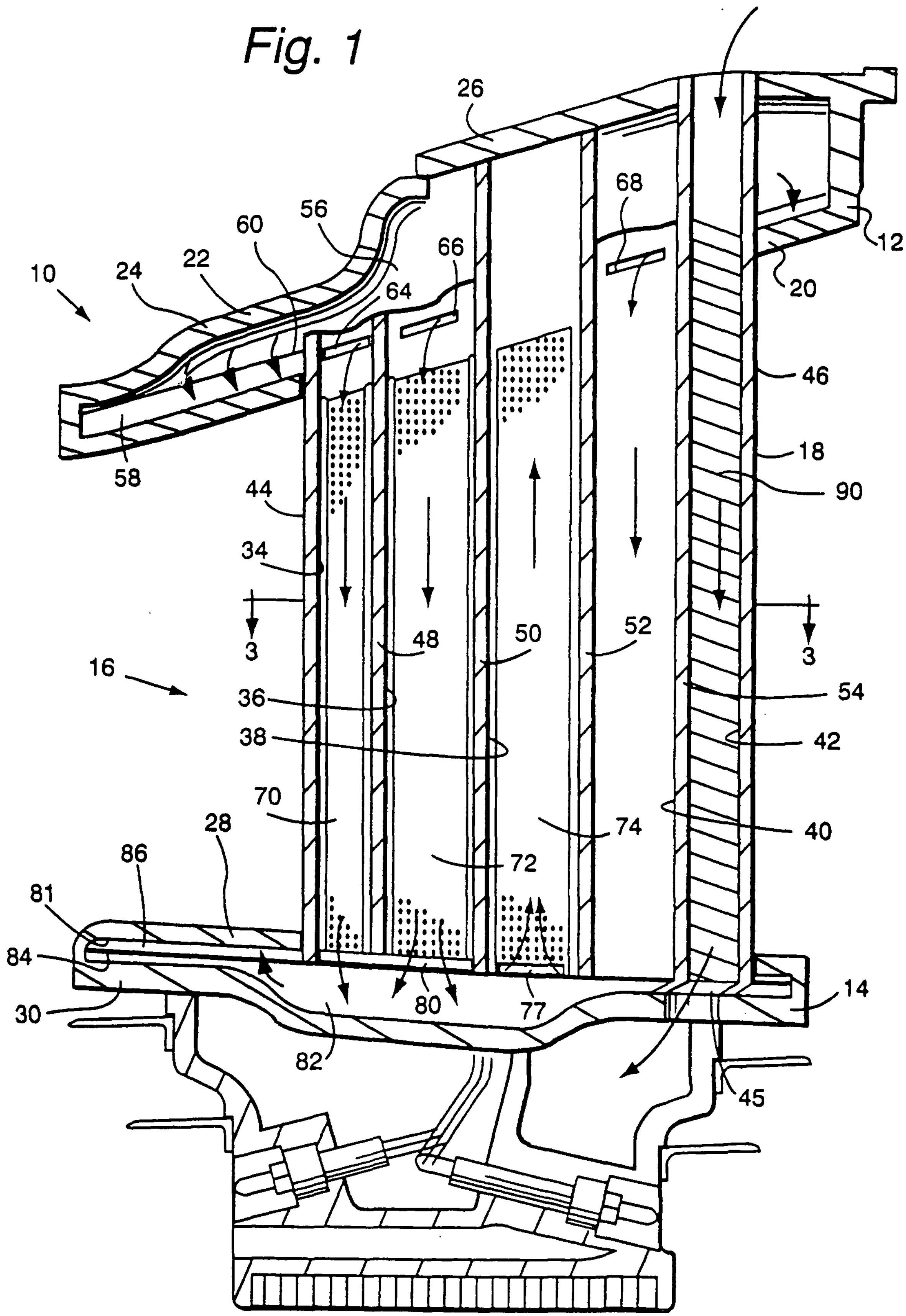
6. A turbine vane segment according to Claim 1 including first, second and third insert sleeves (70, 72, 74) in said first, second and third cavities, respectively, and spaced from interior wall surfaces of the respective cavities, each insert sleeve having an inlet for flowing the cooling medium into the insert sleeve and impingement openings (75) for flowing the cooling medium through the sleeve openings into the space between the sleeve and the cavity for impingement cooling interior wall surfaces of said vane, said first and second sleeves being spaced from and defining respective channels with said interior wall surfaces of said first and second cavities for flowing spent impingement cooling medium from said channels to said compartment of said inner wall, said third sleeve being spaced from and defining a channel with said interior wall surface of said third cavity for receiving the cooling medium flowing through the openings of said third insert sleeve from said compartment of said inner wall and channeling the flow generally radially outwardly of the vane.

7. A turbine vane segment according to Claim 2 including first, second and third insert sleeves in said first, second and third cavities, respectively, and

spaced from interior wall surfaces of the respective cavities, each insert sleeve having an inlet for flowing the cooling medium into the insert sleeve and impingement openings for flowing the cooling medium through the sleeve openings into the space between the sleeve and the cavity for impingement cooling interior wall surfaces of said vane, said first and second sleeves being spaced from and defining respective channels with said interior wall surfaces of said first and second cavities for flowing spent impingement cooling medium from said channels to said inner chamber of said inner wall, said third sleeve being spaced from and defining a channel with said interior wall surface of said third cavity for receiving the cooling medium flowing through the openings of said third insert sleeve from said outer chamber of said inner wall and channeling the flow generally radially outwardly of the vane.

8. A turbine vane segment according to Claim 6 or Claim 7 wherein said insert lie solely in said first, second and third cavities, respectively, said fourth and fifth cavities being void of impingement cooling inserts.

Fig. 1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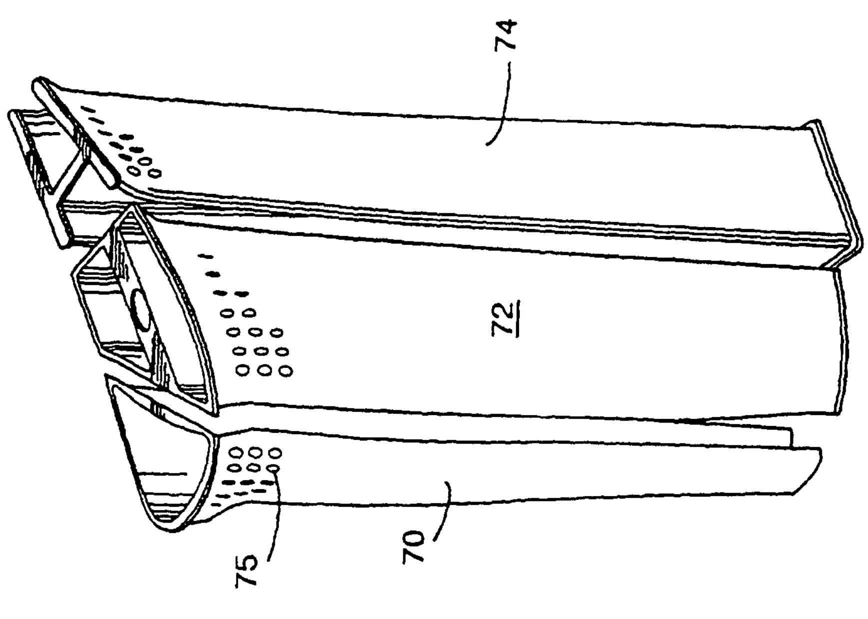


Fig. 2

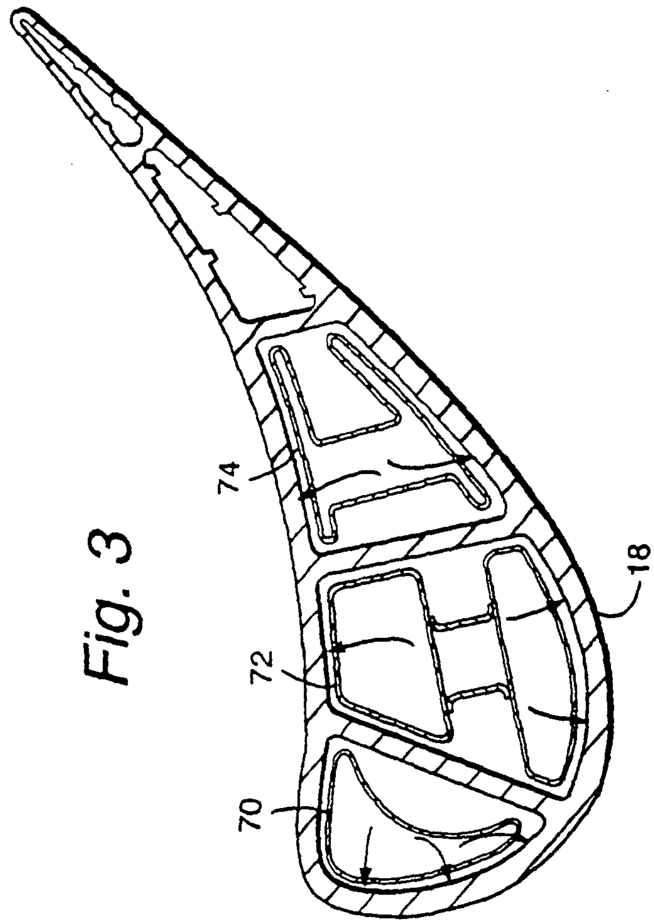
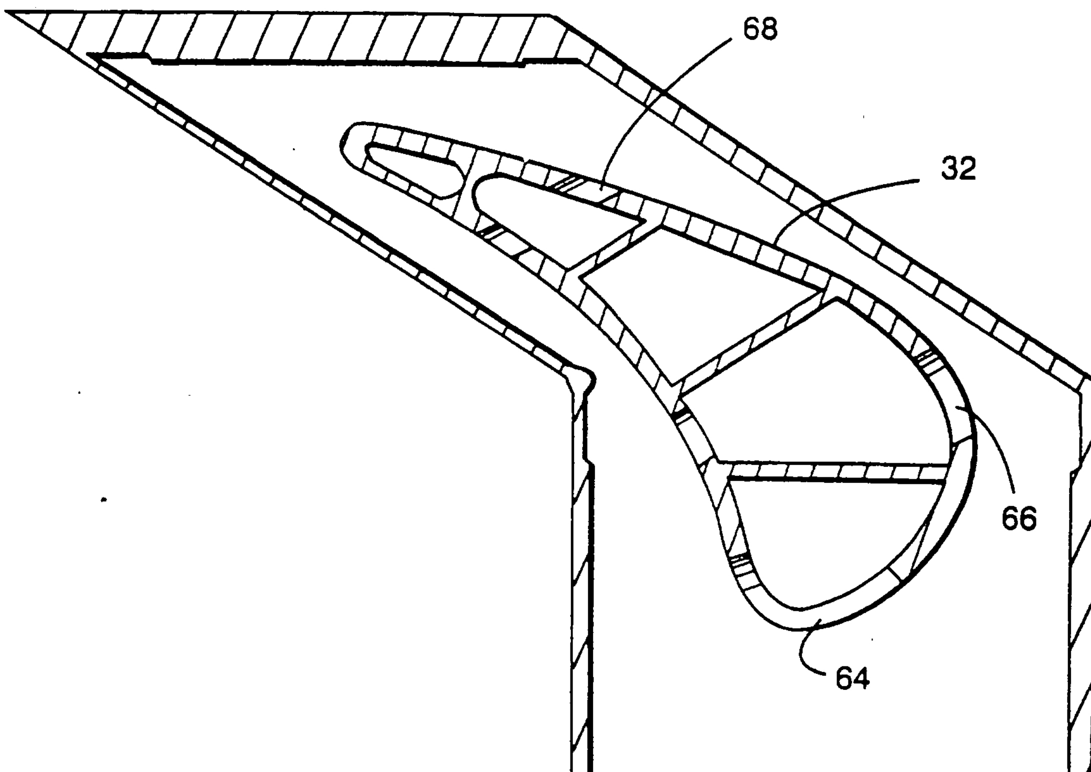


Fig. 3

Fig. 4



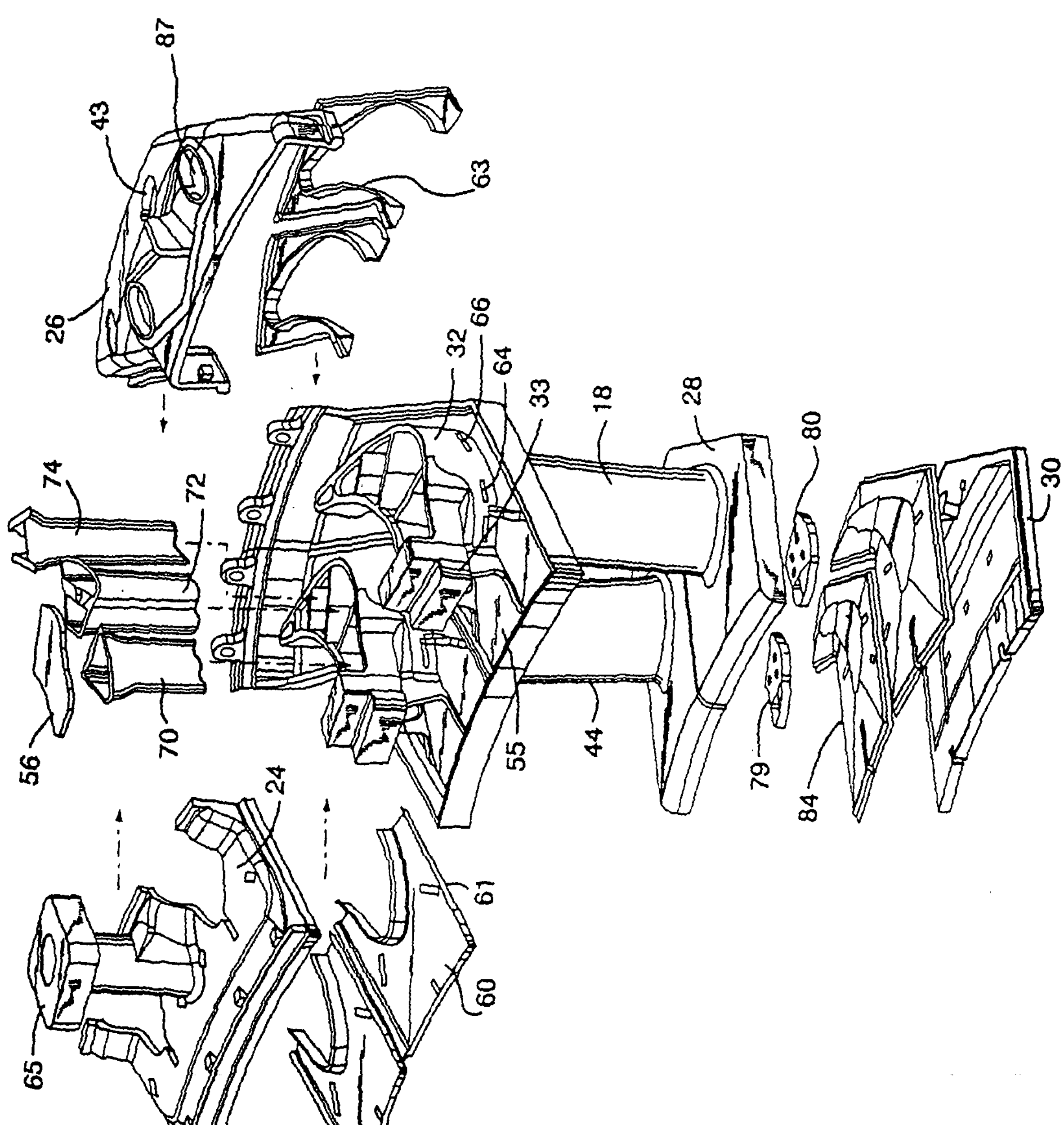


Fig. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 00 31 0376

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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TECHNICAL FIELDS SEARCHED (Int.Cl.7)
F01D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	22 January 2001	Baumann

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